Pit B or not Pit B? The pitfall array is the question.

A.S. Kutt[1,2*] and E.P. Vanderduys[3]

[1.] School of Marine and Tropical Biology, James Cook University, Townsville Queensland, Australia 4811.

[2.] School of Botany, University of Melbourne, Parkville, Victoria Australia 3010.

[3.] CSIRO Sustainable Ecosystems, Ecology Program, PMB PO, Aitkenvale, Queensland, Australia 4814.

[*] Corresponding author. Email alex.kutt@bigpond.com

ABSTRACT

Pitfall trapping is a long established method for trapping terrestrial vertebrates globally. Many variations in bucket and drift fence arrays are used. Recent survey guidelines have been published for Queensland and the Northern Territory. In Queensland a "T" pattern is recommended, and we used data collected over five years to assess whether the use of this array, with the addition of a central bucket (Pit B), results in more captures, particularly in the central bucket. A total of 263 sites representing 1052 bucket samples were examined and the differences in capture abundance in bucket location was tested using analysis of variance. Pitfall bucket location significantly affected the captures of Dasyuridae, Muridae, Agamidae, Pygopodidae, Scincidae ($P<0.1$), and mean abundance was highest in the central Pit B except for Agamidae. There was also significant variation in abundance across habitat type for these families, excluding Dasyuridae, but including Gekkonidae. We conclude that having a central bucket where drift fences join can increase trap success, and this is a function of effective trapping area (i.e. catchment of animal activity and length of drift fence per bucket). Increased captures may have some relationship to habitat type (i.e. small mammals more abundant in grassland habitat). Though this particular array has some benefits in increasing trap success, the use of multiple survey techniques is recommended for any thorough fauna inventory.

Key words: fauna survey, survey methods, pitfall trapping, reptiles, mammals, monitoring

DOI: http://dx.doi.org/10.7882/AZ.2014.028

Introduction

Pitfall trapping is a long established and successful method for the capture of terrestrial vertebrates worldwide (Braithwaite 1983; Cockburn *et al.* 1979; Williams and Braun 1983). The method targets mostly small reptiles and mammals, generally using drift fence to guide animals into bucket-style traps (Morton *et al.* 1988), though small versions of pitfall traps (i.e. plastic vials), usually without fences and with preservative placed at the bottom of the trap, are used for invertebrates (Kutt 2009). Depending on the location and habitat type, the success of pitfall traps can vary with taxon (Catling *et al.* 1997) and in comparison with other methods (e.g. baited box traps versus pitfall for mammals, Umetsu *et al.* 2006). Methods also vary in cost effectiveness (Ribeiro *et al.* 2008), because of labour and installation costs (Perkins *et al.* 2013), but in many cases pitfall trapping is the preferred method for trapping certain taxonomic groups such as reptiles (Garden *et al.* 2007) and families such as blind snakes Typhlopidae (Perkins *et al.* 2013).

The arrangement of pitfall traps and their fences has also received some scrutiny, with initial pitfall trapping used without drift fences, until it was demonstrated that fencing increases captures (Morton *et al.* 1988) for most taxa. The efficacy of the design of fencing for pitfall traps has been investigated for linear arrays (Thompson *et al.* 2005), grids (Friend 1984) and cross-arms or fences at right angles (Hobbs *et al.* 1994). Recently the Northern Territory and Queensland state governments have released guidelines for field surveys and environmental impact assessment, with the intention of promoting a standard survey effort and recommended techniques for environmental impact assessment (Eyre *et al.* 2012; NRETAS 2011). The Queensland pitfall arrangement was T shaped (3 buckets along the top of the T and one near the end of the stem of the T), and used successfully for many years in northern Queensland (Couper *et al.* 2002; Kutt 2004). This array was tested previously for arid Australia, and not significantly more effective than linear designs in that environment (Hobbs *et al.* 1994). We used four buckets, as used in the Northern Territory, although unlike ours, the NT method employs four separate 10 m lines of drift fence with a single bucket (NRETAS 2011). Preferred surveys methods are adopted partly based on literature and partly on speculation regarding their success in the target habitat (Hobbs *et al.* 1994; Umetsu *et al.* 2006). Here we examine the efficacy of a widely used pitfall design using survey data collected over five years (Kutt 2004) to assess whether the use of an array with right-angled fences and a central pitfall favours capture of vertebrates in the central bucket, which has a larger catchment than the peripheral buckets.

Study Area And Methods

The survey sites were all in the Desert Uplands bioregion of north-central Queensland, which lies within Australia's

Figure 1. The pitfall trap array indicating the central bucket, Pit B (Photo by Eric Vanderduys).

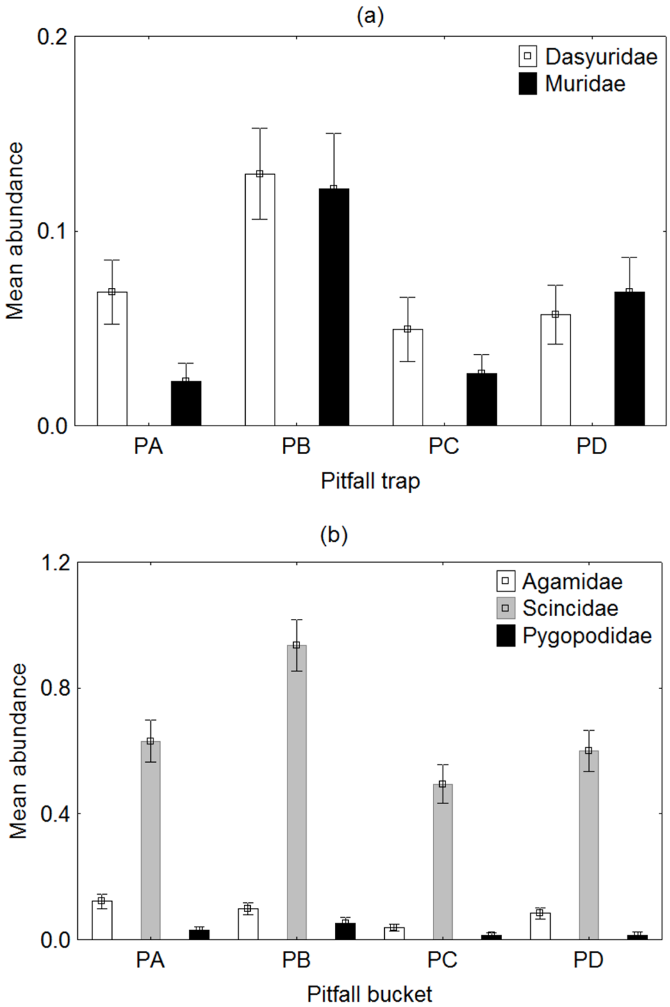

Figure 2. Mean (and standard error) abundance of (a) mammals in the family Dasyuridae and Muridae trapped in each pitfall bucket, and (b) reptiles in the family Agamidae, Scincidae and Pygopodidae, trapped in each pitfall bucket.

northern tropical savannas. The vegetation is dominated by acacia and eucalypt woodlands, but the land also comprises heathlands, ephemeral lakes, dune systems and grasslands. The pitfall surveys were a component of a standardised 1-ha quadrat trap and search array (see Kutt 2004 for further details). The pitfall traps were arranged in a right-angled cross-arm or T configuration, with two lines of drift fence (30 m as the top of the T and 20 m as the stem). Three pitfall buckets were placed on the longest arm at 5-, 15- and 25-m marks, and the one on the shorter arm at the 15 m mark. The fences are joined over the central bucket creating two corners (Figure 1). The pitfall traps were opened for four nights (96 hours) and checked in the morning and afternoon. The bucket number for each capture (A, B, C, D, with B the central bucket and D the bucket on the short arm) was recorded for all captures. The surveys sampled five habitat types: Acacia woodlands, eucalypt woodlands, grasslands (spinifex *Triodia* spp. or Mitchell grasses *Astrebla* spp.), dune / lakeside low woodlands, riparian woodlands and heaths (see Kutt 2004 for further details).

We examined the effects of pitfall bucket location (A, B, C, D) and habitat type on the number of captures using two-way analysis of variance testing the effect of pitfall bucket location (A, B, C, D), habitat type and interaction on the number of captures. The data used in the analysis were the total abundance per family in each bucket over the four day trapping period for each of the 263 sites sampled. We used Statistica for all analyses (StatSoft Inc. 2011). Significance is accepted when $P<0.1$.

Results

A total of 263 1 ha quadrats were surveyed, representing 1052 pitfall bucket samples (or 4208 trap-nights). We captured 1236 vertebrates, representing 2 families of

Table 1. The results of the two-way analysis of variance testing the effect of pitfall bucket, habitat type and interaction on captures. Two mammal families and seven reptile families were examined. F is the F-ratio, and P the significance level. Bold indicates a result with at least P<0.1 significance.

Family	Pitfall bucket		Habitat		Pitfall x Habitat	
Df	3		6		15	
	F	P	F	P	F	P
Mammals						
Dasyuridae	4.02	0.007	1.62	0.139	1.04	0.410
Muridae	6.36	<0.001	1.94	0.072	0.34	0.996
Reptiles						
Agamidae	3.46	0.016	2.24	0.037	0.51	0.954
Elapidae	1.23	0.297	0.91	0.483	1.33	0.159
Gekkonidae	0.52	0.667	3.73	0.001	0.65	0.858
Pygopodidae	2.26	0.080	5.93	<0.001	1.55	0.065
Scincidae	8.28	<0.001	17.66	<0.001	1.05	0.400
Typhlopidae	2.00	0.113	0.38	0.892	0.67	0.839
Varanidae	1.74	0.156	1.71	0.116	0.34	0.996

Table 2. The mean abundance (and standard error) of mammals and reptiles (by family) captured in each of the pitfall buckets. Bold indicates the highest mean value.

Family	Pit A	Pit B	Pit C	Pit D
Mammals				
Dasyuridae	0.07 (0.02)	0.13 (0.02)	0.05 (0.02)	0.06 (0.02)
Muridae	0.02 (0.01)	0.12 (0.03)	0.03 (0.03)	0.07 (0.02)
Reptiles				
Agamidae	0.12 (0.02)	0.10 (0.02)	0.04 (0.02)	0.08 (0.02)
Elapidae	0.01 (0.01)	0.03 (0.01)	0.02 (0.01)	0.02 (0.01)
Gekkonidae	0.18 (0.03)	0.24 (0.04)	0.21 (0.04)	0.21 (0.04)
Pygopodidae	0.03 (0.01)	0.05 (0.02)	0.02 (0.02)	0.02 (0.01)
Scincidae	0.63 (0.07)	0.94 (0.08)	0.49 (0.08)	0.6 (0.06)
Typhlopidae	0 (0)	0.02 (0.01)	0.01 (0.01)	0 (0)
Varanidae	0.02 (0.01)	0.03 (0.01)	0.01 (0.01)	0.03 (0.01)

Table 3. The mean abundance (and standard error) of one mammal and three reptile families, of which habitat was a significant individual or interacting factor (with pitfall bucket number) in the two-way analysis of variance. Bold indicates the highest mean value.

Family	Acacia	Eucalypt	Grassland	Dune/Lake	Riparian	Heath
Mammals						
Muridae	0.02 (0.01)	0.07 (0.01)	0.08 (0.03)	0.03 (0.02)	0.07 (0.05)	0 (0)
Reptiles						
Agamidae	0.03 (0.01)	0.10 (0.01)	0.10 (0.03)	0.13 (0.05)	0.11 (0.08)	0 (0)
Pygopodidae	0.02 (0.01)	0.03 (0.01)	0.08 (0.04)	0.02 (0.02)	0 (0)	0 (0)
Scincidae	0.21 (0.05)	0.85 (0.05)	0.11 (0.03)	1.10 (0.16)	1.29 (0.36)	0.46 (0.13)

mammals (Dasyuridae n = 80, Muridae n = 63) and 7 of reptiles (Agamidae n = 90, Elapidae n = 21, Gekkonidae n = 221, Pygopodidae n = 30, Scincidae n = 700, Typhlopidae n = 6, Varanidae n = 25). Of the 1052 pitfall bucket samples, 446 recorded no animal and 606 returned at least one individual animal (see Kutt 2004 for further details).

Pitfall location had a significant effect ($P<0.1$) on Dasyuridae, Muridae, Agamidae, Pygopodidae and Scincidae captures, and mean abundance was highest in trap B, except for Agamidae (Fig. 2). There was also a significant effect of habitat type for these families, excluding Dasyuridae, but including Gekkonidae. We found no significant interaction between trap location and habitat type except for Pygopodidae (Table 1). All families, except Agamidae, were more likely to be captured in Pit B (Table 2). For families where habitat was a significant effect for both pit location and habitat, mean abundance was highest in grasslands (Muridae), dune / lake habitat (Agamidae) and riparian habitat (Scincidae) (Table 3).

Discussion

Though there is no perfect methodological formula for maximising trap success, and recognising that different methods suit different habitats, location and taxa (Garden *et al.* 2007; Perkins *et al.* 2013), we found that the use of a central pitfall bucket results in higher captures of particular taxa (mammals) and families (Scincidae, Pygopodidae). For a given set-up effort (digging 4 holes and building 50 m of drift fence), having a T arrangement including central pitfall trap, is likely to increase survey efficacy over other designs. Improving trapping success is an important consideration with respect to environmental assessments for development applications. Long or multiple site visits are required to adequately identify species present at a site, and methods need to maximise species richness and accumulation for a site (Perkins *et al.* 2013; Thompson *et al.* 2005). Furthermore, this design is effective for recording families that are especially difficult to detect by other methods such as active searching (e.g. Typhlopidae, Pygopodidae).

The increase in trapping rate in the central bucket compared to those on the arms will be related to the length of fence leading to each bucket, the complexity of fence array leading to each bucket and therefore the effective trapping area confronting moving animals. At the most simplistic level, Pit B has a maximum total of 35 m of drift fence leading to the bucket (total of drift fence from it to the next nearest buckets), whereas as Pit A and C have 15 m and Pit D 20 m. An increase in drift fence should have a simple correlative relationship to increase in trap abundance. More complex analysis using conceptual models of the trapping array as an obstacle and the likelihood of the animal capture based on the catchment area of the drift fence and the diameter of the buckets have been undertaken in the past (Luff 1975). Though we don't believe such a detailed analysis

is warranted here, intuitive assessment of the effective trapping area of Pit B suggests it is higher than the other three pitfall traps in that the direct pathway of animal movement towards the perimeter of the bucket is not hindered by drift fence, whereas for the other buckets, sections of drift fence reduce the direct access by between 20-30%. This might explain the magnitude of difference in captures between the bucket locations.

The significant effect of habitat is probably due to the combination of the higher abundance of certain taxa in particular habitats and the effectiveness of drift fences in these habitats. For example, Muridae and Pygopodidae tended to be more abundant in grasslands (Spinifex and Mitchell grass); small mammals are typically more abundant where ground cover is higher (Kutt and Gordon 2012) . Tall ground cover might allow some animal passage over the fences (e.g. Agamidae), or conversely bare ground may increase captures as animals trapped on the fence line might panic, move more quickly, and increase their risk of falling into the traps. It seems that for most habitats, however, the array presented in the Terrestrial Vertebrate Fauna Survey Guidelines for Queensland (Eyre *et al.* 2012) and used extensively in northern Queensland surveys (Kutt and Fisher 2011; Vanderduys *et al.* 2012) will increase trap success by the use of a central trap (B). We recognise that we did not test different types of array (e.g. single drift fences versus joined), and that there might be more effective pitfall patterns for tropical savanna environments (NRETAS 2011). A useful future comparative exercise would be to test these data against that collected from alternative techniques for the same vertebrate fauna taxa. Such a study has been undertaken in eucalypt forest near Sydney (Webb 1999) demonstrating a clear advantage in long (40 m) over short (4 m) drift fences, but importantly not reaching any conclusion about optimum drift fence length. Similarly in western New South Wales comparisons of different bucket size and drift fence material suggested a mixture was warranted (Ellis 2013). This is an area in need of further study, because of the logistical considerations of installing drift fences.

The higher captures of Dasyuridae, Muridae, Pygopodidae and Scincidae in the central pitfall bucket are in keeping with other studies of different pitfall arrays. In other tropical forests, pitfall traps are important for targeting cryptic species and lizards (Ribeiro *et al.* 2008), and the corollaries in our study are Pygopodidae and Scincidae. Small tropical mammals in other tropical regions are also better represented in pitfalls than in baited box traps (e.g. Sherman traps) (Umetsu *et al.* 2006). In arid environments where the fauna can be less abundant and more spatially dispersed (Greenville *et al.* 2012), pitfall trapping is the common trapping method for both mammals and reptiles, and long linear arrays, with higher pitfall trap density and surveyed over long periods are more effective (Hobbs *et al.* 1994; Moseby and Read 2001). In sub-tropical forest environments, where much of the mammal fauna is scansorial and arboreal, pitfall traps perform poorly compared to baited box and cage traps, and searching, and are not recommended for use (Catling *et al.* 1997).

In this study we have demonstrated that a T-shaped array has benefits of an increased trap success in the central pitfall bucket, although there is general consensus that the use of multiple survey techniques, both trapping and observation, is necessary for any thorough and complete fauna inventory survey (Garden *et al.* 2007; Perkins *et al.* 2013; Ribeiro *et al.* 2008).

Acknowledgments

Surveys were conducted under the conditions of Nature Conservation Act Scientific Purposes Permit NO/001480/96/SAA and NO/001480/99/SAA (EPA) and 1037/1038, 1170, 1359, 1513 and 1682 (DNRM). The survey of the Desert Uplands bioregion was funded by the Australian Heritage Commission's National Estate Grant program and the Tropical Savanna CRC. Jeanette Kemp (Australian Wildlife Conservancy) assisted with many of the Desert Uplands surveys.

References

Braithwaite, R.W. 1983. A comparison of two pitfall trap systems. *Victorian Naturalist* **100:** 163-166.

Catling, P.C., Burt, R.J., and Kooyman, R. 1997. A comparison of techniques used in a survey of the ground-dwelling and arboreal mammals in forests in north-eastern New South Wales. *Wildlife Research* **24**: 417-432. http://dx.doi.org/10.1071/WR96073

Cockburn, A., Fleming, M., and Wainer, J. 1979. The comparative effectiveness of drift fence pitfall trapping and conventional cage trapping of vertebrates in the Big Desert, north-western Victoria. *Victorian Naturalist* **96**: 92-95.

Couper, P.J., Amey, A.P., and Kutt, A.S. 2002. A new species of Ctenotus (Scincidae) from central Queensland. *Memoirs of the Queensland Museum* **48:** 85-91.

Ellis, M. 2013. Impacts of pit size, drift fence material and fence configuration on capture rates of small reptiles and mammals in New South Wales rangelands. *Australian Zoologist* **36:** 404-12. http://dx.doi.org/10.7882/AZ.2013.005

Eyre, T.J., Ferguson, D.J., Hourigan, C.L., Smith, G.C., Mathieson, M.T., Kelly, A.L., Venz, M.F., and Hogan, L.D. 2012. *Terrestrial Vertebrate Fauna Survey Assessment Guidelines for Queensland*. (Department of Science, Information Technology, Innovation and the Arts, Queensland Government: Brisbane)

Friend, G.R. 1984. Relative efficiency of two pitfall-drift fence systems for sampling small vertebrates. *Australian Zoologist* **21:** 423-33.

Garden, J.G., McAlpine, C.A., Possingham, H.P., and Jones, D.N. 2007. Using multiple survey methods to detect terrestrial reptiles and mammals: what are the most successful and cost-efficient combinations? *Wildlife Research* **34:** 218-227. http://dx.doi.org/10.1071/WR06111

Greenville, A.C., Wardle, G.M., and Dickman, C.R. 2012. Extreme climatic events drive mammal irruptions: regression analysis of 100-year trends in desert rainfall and temperature. *Ecology and Evolution* **2**: 2645-2658. http://dx.doi.org/10.1002/ece3.377

Hobbs, T.J., Morton, S.R., Masters, P., and Jones, K.R. 1994. Influence of pit-trap design on sampling of reptiles in arid spinifex grasslands. *Wildlife Research* **21**: 483-489. http://dx.doi.org/10.1071/WR9940483

Kutt, A.S. 2004. Patterns in the composition and distribution of the vertebrate fauna, Desert Uplands Bioregion, Queensland Doctor of Philosophy Thesis, School of Marine and Tropical Biology, James Cook University of North Queensland, Townsville

Kutt, A.S. 2009. The relative effect of fire and grazing on ants in tropical savanna woodland in north-eastern Australia. *Ecological Management and Restoration* **10**: 233-235. http://dx.doi.org/10.1111/j.1442-8903.2009.00494.x

Kutt, A.S., and Fisher, A. 2011. Increased grazing and dominance of an exotic pasture (Bothriochloa pertusa) affects vertebrate fauna species composition, abundance and habitat in savanna woodland. *The Rangeland Journal* **33**: 49-58. http://dx.doi.org/10.1071/RJ10065

Kutt, A.S., and Gordon, I.J. 2012. Variation in terrestrial mammal abundance on pastoral and conservation land tenures in north-eastern Australian tropical savannas. *Animal Conservation* **15**: 416-425. http://dx.doi.org/10.1111/j.1469-1795.2012.00530.x

Luff, M.L. 1975. Some features influencing the efficiency of pitfall traps. *Oecologia* **19**: 345-357.

Morton, S.R., Gillam, M., Jones, K.R., and Fleming, M. 1988. Relative efficiency of different pit-trap systems for sampling reptiles in spinifex grasslands. *Wildlife Research* **15**: 571-577. http://dx.doi.org/10.1071/WR9880571

Moseby, K.E., and Read, J.L. 2001. Factors affecting pitfall capture rates of small ground vertebrates in arid South Australia. II. Optimum pitfall trapping effort. *Wildlife Research* **28**: 61-71. http://dx.doi.org/10.1071/WR99058

NRETAS 2011. *Environmental Assessment Guidelines for the Northern Territory: Terrestrial Fauna Survey.* (Northern Territory Government: Darwin)

Perkins, G., Kutt, A., Vanderduys, E., and Perry, J. 2013. Evaluating the costs and sampling adequacy of a vertebrate monitoring program. *Australian Zoologist* **36:** 373-380.

Ribeiro, M.A., Gardner, T.A., and Avila-Pires, T.C.S. 2008. Evaluating the Effectiveness of Herpetofaunal Sampling Techniques across a Gradient of Habitat Change in a Tropical Forest Landscape. *Journal of Herpetology* **42**: 733-749.

StatSoft Inc. 2011.STATISTICA (data analysis software system), version 10. In '.' (www.statsoft.com.)

Thompson, S.A., Thompson, G.G., and Withers, P.C. 2005. Influence of pit-trap type on the interpretation of fauna diversity. *Wildlife Research* **32**: 131-137. http://dx.doi.org/10.1071/WR03117

Umetsu, F., Naxara, L., and Pardini, R. 2006. Evaluating the efficiency of pitfall traps for sampling small mammals in the Neotropics. *Journal of Mammalogy* **87:** 757-765. http://dx.doi.org/10.1644/05-MAMM-A-285R2.1

Vanderduys, E.P., Kutt, A.S., and Kemp, J.E. 2012. Upland savannas: the vertebrate fauna of largely unknown but significant habitat in north-eastern Queensland. *Australian Zoologist* **36**: 59-74.

Webb, G.A. 1999. Effectiveness of pitfall/drift-fence systems for sampling small ground-dwelling lizards and frogs in southeastern Australian forests. *Australian Zoologist* **31:** 118-126.

Williams, D.F., and Braun, S.E. 1983. Comparison of pitfall and conventional traps for sampling small mammal populations. *The Journal of Wildlife Management* **47**: 841-845.